CHAINME: Fast Decentralized Finding of Better Supply Chains

(Extended Abstract)

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ABSTRACT

Decentralized Supply Chain Formation (SCF) appears as a highly intricate task because agents only possess local information, have limited knowledge about the capabilities of other agents, and prefer to preserve privacy. State-of-the-art decentralized SCF approaches can either: (i) find Supply Chains (SC) of high value at the expense of high resources usage; or (ii) find SCs of low value with low resources usage. This work presents CHAINME, a novel decentralized SCF algorithm. Our results show that CHAINME finds SCs with higher value than state-of-the-art decentralized algorithms whilst decreasing the amount of resources required from one up to four orders of magnitude.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent Systems

General Terms

Algorithms, Economics, Experimentation

Keywords

Supply chain, belief propagation, scalability

1. INTRODUCTION

Supply Chain Formation (SCF) is the process of determining the participants in a supply chain (SC), who will exchange what with whom, and the terms of the exchanges [6]. This problem has been already tackled by the AI literature. Initial contributions [7, 1] addressed the problem by means of combinatorial auctions (CAs) that compute the optimal SC allocation in a centralized manner. Since even finding a feasible SC allocation is NP-Complete [5], sufficiently large SCF problems will be intractable, hence hindering the scalability of the global optimization performed by centralized, auction-based approaches. Furthermore, as argued in [6], even when the computation is tractable, no single entity may have global allocative authority to compute allocations over the entire SC. Thus, there is a need for *approximate distributed* solutions to the SCF problem.

In [6], Walsh et al. proposed to solve the SCF problem in a fully decentralized manner (SAMP-SB). Each good in the SC is auctioned separately and all auctions run simultaneously without direct coordination. Therefore, each auction allocates a single resource considering the offers to buy or sell submitted by agents. Nevertheless, the approach proposed by Walsh et al. suffers from high communication requirements, as discussed in [4].

Later on, Winsper et al. [8] cast the decentralized SCF problem as an optimization problem that can be approximated using (max-sum) loopy belief propagation [2]. Nonetheless, as shown in [3], the problem representation employed by Winsper et al. leads to exponential memory and communication requirements that largely hinder its scalability. Thus, Penya-Alba et al. provide in [3] a scalable approach to the decentralized SCF problem through a new encoding of the SCF problem into a binary factor graph (RB-LBP). However, as we show in this paper, as the number of participants increases, the algorithm in [3] is unable to find SCs whose value are close to the optimal.

To summarize, state-of-the-art decentralized SCF algorithms can either: (i) find high-valued SCs at the expense of high resources usage; or (ii) find low-valued SCs with low resources usage. We present CHAINME, a novel decentralized SCF algorithm that assesses higher-valued SCs than state-of-the-art decentralized algorithms. Furthermore, the resources required by CHAINME are from one up to four orders of magnitude less than those used by other algorithms.

2. CHAINME

In this section we describe our approach for decentralized SCF, the so-called CHAINME (CHaining Agents IN Mediated Environments). CHAINME aims at providing an algorithm for decentralized SCF that finds high-valued SCs using as little resources as possible.

CHAINME is a message-passing algorithm involving participants and mediators. Moreover, each SC participant (be it seller of buyer) is represented by a participant agent, whereas each good is represented by a mediator agent who arbitrates the interactions of the agents interested in that good. Participants only communicate with the mediators of the goods they want to sell or buy. Likewise, each mediator only communicates with the participants willing to buy or sell the good she mediates.

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Agents in CHAINME follow a established protocol that has two main phases. During the first phase, each participant finds out how valuable she is for the SC as a whole when she is active (i.e. selling or buying goods). Based on that information, during the second phase, each participant decides whether to be active (part of the SC) or not. Section 2.1 details the first phase, whereas section 2.2 details the second phase.

2.1 Assessing How Valuable Participants Are

During this phase, agents exchange messages iteratively in turns, from participants to mediators and from mediators to participants. First, each participant submits her offers, encoding her willingness to participate in the SC, to the mediators she is connected to. After that, each mediator communicates to each of her neighboring participants an approximation of their local social value for that good. In general, the social value for a group of agents of an event is the difference between the aggregated benefit for those agents if the event happens and the aggregated benefit for those agents if the event does not happen. In our case, mediators send to each participant an aggregate of the social values of the other participants, for the participant to be active. That is, the benefit that the other agents connected to the mediator would obtain if the participant is active minus the benefit that the other agents connected to the mediator would obtain if the participant is inactive. After receiving mediators' messages, participants use the received social value estimates to update their offers, which are subsequently sent to mediators. This process continues until messages do not change from iteration to iteration or a maximum number of iterations is reached. At this point, each participant knows how valuable she is for the SC.

2.2 Assessing the Supply Chain Configuration

This is achieved by iterating a two-step process. During the first step, participants determine whether they are available to be active. During the second step, mediators communicate to participants whether they are eligible to be active.

Each participant decides whether she is available to be active if that is profitable for the SC as a whole. This occurs whenever the addition of the received social values of each of the goods she is connected to together with her activation cost is positive. After each participant has determined whether she is available to be active or not, she sends her availability status to all of her neighboring mediators. Once a participant decides that she is unavailable, she will no further change her status. Each mediator, after receiving the availability status from all her neighboring agents, determines a pairing of profitable buyers and sellers by discarding participants that reported themselves as unavailable. After that, the mediator sends each available participant whether she is active or inactive in the SC. When a participant receives the status request from each of her neighboring mediators, she decides to be available only if all of her neighboring mediators requested her to be active. She sends her availability status to all the mediators she is connected with. This process continues iteratively until no participant changes her availability status. Participants who are available when this occurs will be the active participants in the SC and will compose the SC configuration.

3. EXPERIMENTAL EVALUATION

We benchmarked CHAINME against SAMP-SB and RB-LBP in large networks (up to 500 participants and 50 goods) similar to those described in [3]. In terms of solution quality, both CHAINME and SAMP-SB find solutions that are close to the optimal (>95%). However, RB-LBP's fall bellow the 20% of the optimal value for the 500 participants scenario. Furthermore, the number of problems optimally solved by SAMP-SB and RB-LBP rapidly decreases as the number of participants increases (<5% with 500 participants). By contrast, CHAINME is able to find the optimal solution in over 70% of the problems (even with 500 participants).

In terms of resource requirements, CHAINME uses from one up to four orders of magnitude less bandwidth than the other methods. Moreover, CHAINME requires over two orders of magnitude less computation than RB-LBP or SAMP-SB. Finally, our analysis show that the three methods have similar memory requirements.

4. CONCLUSIONS AND FUTURE WORK

We have introduced CHAINME, a novel decentralized SCF algorithm where agents use the concept of local social value to determine their worth to the SC as a whole. In our experiments, CHAINME outperforms state-of-the-art algorithms RB-LBP and SAMP-SB in terms of the value of the SCs found. Furthermore, CHAINME consumes less than one tenth of the communication and one percent of the computational resources used by those algorithms.

The experiments show that the SC values obtained by CHAINME are optimal much more often than the state-of-the-art algorithms. Thus, we consider that it could be an approximate, low resources alternative to optimal centralized approaches (such as integer linear programming) in very large SCF scenarios. We plan to explore that path in the future.

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